ABSTRACT

The study of the Mohorovičić discontinuity or Moho is a fundamental topic in different fields of geosciences. It is necessary to understand the dynamics of the Earth’s interior, to study the gravitational signal of anomalous crustal density distribution and it can be usefully used also in the geoid quasidetermination. The Moho can be determined by means of seismic and gravimetric methods. Since these two methods are based on different hypotheses as well as different types, qualities and distributions of data they will yield in general also different results. In particular it is well known that seismic methods suffers for lack of observations while the gravitational ones are usually characterized by an oversimplification of the problem due to the fact that in order to guarantee the uniqueness of the solution of the inverse gravitational problem by simplifying hypothesis should be used.

The aim of this work is to overcome these limitations by combining the CRUST2.0 model (containing the seismic and geological information) with gravity observations from the GOCE mission on the bases of a priori information on the accuracy of CRUST2.0 model and on the GOCE observation errors.

The result is an update of the CRUST2.0 Moho model with a resolution of 1° x 1° which contains seismic and geological information and it is a consistent with the actually observed gravity field.

The differences between the new Moho model and the CRUST2.0 are of the order of few kilometers: less than 1km the mean value and about 4km the standard deviation. However in some regions like South America, Alaska and Antarctica differs with a higher standard deviation of about 7.0 km are present.

Some preliminary comparisons with local Moho profiles seem to confirm that in these regions the updated Moho is more consistent to local models and to seismic data than the CRUST2.0.

INVERSION METHOD FOR GOCE DATA AND CRUST2.0 MERGING

1) INVERSION OF THE RESIDUAL GRID

GOCE space wise grid is corrected in order to be as close as possible to the two-layer model hypothesis:

\[ \Delta \sigma^i (P) = \sigma^{GOCE}(P) - (T_{\text{Elastic}}(P) - T_{\text{Elastic}}(P) - T_{\text{Elastic}}(P) - T_{\text{Elastic}}(P) - T_{\text{Elastic}}(P)) \]

A spherical harmonics analysis of the residual grid is performed up to degree and order 359 obtaining the coefficients of the residual gravity field \( T_{\text{Elastic}} \). Using a linearized expression \( \Delta \sigma^i \) coefficients can be related to the coefficients of a functional \( \Delta \) defined as the product between the Moho undulation \( \Delta \rho_{\text{Moho}} \) with respect to a reference spherical Moho of radius \( \varepsilon \) and its density contrast \( \Delta \rho_{\text{Moho}} \). A priori Moho

Not that if a model of \( \Delta \rho_{\text{Moho}} \) is known a GOCE only Moho can be estimated. The linearization of the transfer function can be estimated by means of a “closed-loop test”:

\[ \Delta \rho_{\text{Moho}} = \Delta \rho_{\text{obs}} + \Delta \rho_{\text{model}} \]

2) CRUST2.0 MERGING

CRUST2.0 model describes the crustal structure by giving information on thickness and density of seven global components (oceanic, ice, soft and hard sediments, upper, middle and lower crust) on a grid with a resolution of 2° x 2°. Moreover, for each cell of the grid, the crustal type (e.g. oceanic, continental plateau, sub-continental regions, etc.) and the upper mantle density are also given.

The gravitational effect of the CRUST2.0 model has been computed on a 0.5° x 0.5° grid in terms of \( \Delta \rho \) at GOCE satellite altitude by means of numerical integration. The computed effect has been reduced to a zero-mean signal by removing a constant value. The comparison between CRUST2.0 integrated signal and GOCE observations shows that the gravitational effect of CRUST2.0 is about one order of magnitude larger than those observed by GOCE, i.e., the standard deviation of the \( \Delta \rho \) grid is 1015 mE for the CRUST2.0 effect and 231 mE for GOCE observations.

CONCLUSION AND FUTURE PERSPECTIVE

The resulting model takes advantage of the geological information inside CRUST2.0, especially in the areas where the two-layer hypothesis is weak and in the polar regions where GOCE data are not available.

The closed-loop test shows that GOCE observation error (up to degree 180) can be neglected in the Moho estimation procedure and that the linearization error is less than 1 km (std) globally. This implies that GOCE space-wise grids can be used to constrain the relation between density and Moho depth with very high accuracy.

The computed Moho global model is well consistent with the actual gravity field and it is delivered together with its error estimates, thus overcoming the main limitations of CRUST2.0.

The main drawback of the method is in the definition of the densities of the crustal model that reverts on errors up to 6 km.

As for the future perspectives, the GOCE gravimetric model could be improved by using more refined density models for the crustal bedrock, e.g. taking into account of recent models of geological provinces. Also the combination could be improved directly adding information from CRUST2.0 inside the inversion procedure.

COMPARISON BETWEEN GOCE AND CRUST2.0 GRAVITY SIGNAL

The two main input datasets that are used for the Moho determination are:

1) GOCE grid of second radial derivative of the gravitational potential \( \Delta \rho \) at mean satellite altitude computed by applying the so-called space-wise approach to GOCE observations. It has a resolution of 0.5° x 0.5° and it is supplied with the corresponding set of 400 Monte Carlo samples or error grids to be used for covariance modeling.

2) CRUST2.0 model describes the crustal structure by giving information on thickness and density of seven global components (oceanic, ice, soft and hard sediments, upper, middle and lower crust) on a grid with a resolution of 2° x 2°. Moreover, for each cell of the grid, the crustal type (e.g. oceanic, continental plateau, sub-continental regions, etc.) and the upper mantle density are also given.

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COMPARISON WITH SIMILAR SOLUTIONS

A similar procedure to the one proposed has been applied by Sjöberg and Baghehbandi 2011 to estimate a global crustal model based on EGM08 and CRUST2.0.

Apart from the use of GOCE data instead of the EGM08 model, other significant differences with respect to the Moho computed by Sjöberg and Baghehbandi 2011 are in the reduction of gravimetric observation as well as in the choice of the final combination weights.

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